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SECONDARY BATTERY SESSION IMPROVED AIRCRAFT BATTERY, (U)  
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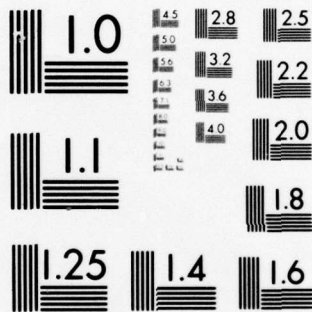
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## Secondary Battery Session

# IMPROVED AIRCRAFT BATTERY

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### Introduction

At the 23rd Annual Power Sources Conference a proposed redesign<sup>1</sup> of a standard 19-cell 22.8 volt nickel-cadmium aircraft battery (BB-433/A) rated at 30 Ah at the one hour rate was discussed. Battery BB-433/A has been widely assigned in Army aircraft and has been the subject of many failure reports from the field. Since that time, efforts have been spent on the development of the redesigned battery.<sup>2</sup>

Simulated aircraft service cycling tests and other electrical and environmental tests were performed on standard and re-designed batteries to determine the feasibility of the redesign concept.

### Battery Components

a. *Monoblock*—The redesigned battery consists of four five-cell plastic (ABS) monoblocks arranged in two rows as

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compared to three rows of individual cells contained in the conventional BB-433/A battery. Advantages of the multicell monoblock concept are:

- The center row of cells is eliminated which ameliorates the heat dissipation problem.
- Increased rigidity of the battery is achieved with dampening of vibration and shock forces on the intercell hardware and internal components.
- More efficient use is made of the internal volume of the battery allowing an increase in electrode area and additional electrolyte.

(1) *Configuration*—A comparison of the external dimensions of the five cell monoblock with that of the BB-600/A cell, which is used in the standard Battery BB-433/A, is shown below:

|           | Length | Width   |         | Height |
|-----------|--------|---------|---------|--------|
|           |        | 1 cell  | 5 cells |        |
| BB-600/A  | 3-1/8" | 1-3/8"  | 6-7/8"  | 8-5/8" |
| Monoblock | 4-5/8" | 1 1/16" | 4-3/4"  | 9-0"   |

(2) *Electrodes*—Two electrode designs were constructed for use in cells of the monoblock. One design was 0.030" thick and offered a direct comparison with the same thickness electrode generally used in Battery BB-433/A. The other was a .021" thick electrode and was fabricated to study the effect of an increased number of thinner plates. Characteristics of the monoblock cell electrodes are compared below with those of BB-600/A cell electrodes.

|           | Thickness | Length | Width  | Number/Cell | Area(in) <sup>2</sup> |
|-----------|-----------|--------|--------|-------------|-----------------------|
| BB-600/A  | .030"     | 6"     | 2-3/4" | 23          | 363                   |
| Monoblock | .030"     | 5"     | 4-1/2" | 21          | 450                   |
| Monoblock | .021"     | 5"     | 4-1/2" | 29          | 630                   |

(3) *Separators*—Prior to selection of the final separator design, an evaluation was made of seven different combinations and thicknesses of nylon, polypropylene, and cellophane. While a .007" thick single layer combination of polypropylene and nylon looked promising at normal and high temperatures under high rate conditions, it behaved poorly at -40°F. In view of the better overall performance characteristics of a .003" woven nylon/.0015" cellophane/.003" woven nylon (N-C-N) separator for the type of service required for aircraft battery use compared to the seven separator designs investigated, all of the final monoblock batteries were fabricated with the "N-C-N" separator combination material.

(4) *Current Collecting Hardware*—Since the electrodes in the cells of the monoblock are shorter than in conventionally designed batteries, special consideration had to be given to the use of a long electrode tab and terminal hardware design. To minimize the resistance and the generation of heat as much as possible, the tabs were extended to a spotwelded region on the electrodes 1-1/4" long instead of the usual 1/2". Each cell terminal was machined from 3/4 square steel bar stock. The upper portion of the terminal had a conventional round threaded design.

(5) *Electrolyte*—The headspace in cells of the monoblock is 3-3/4" compared to 2-1/4" in the standard BB-600/A. This extra space was utilized to hold a larger volume of electrolyte above the plates. The volume of electrolyte above the plates in a cell of the monoblock is 4.93 cubic inches (1-1/4" above electrodes), as compared to .79 cubic inches in the BB-600/A

cell (1/4" above electrodes). The extra electrolyte increases the heat capacity of the battery and allows the monoblock battery to remain flooded throughout its cycling regime.

(6) *Electrolyte Sight Devices*—In order to facilitate the maintenance of the electrolyte levels, sight devices were permanently installed in each cell cover of the monoblock batteries (See Figure 1).

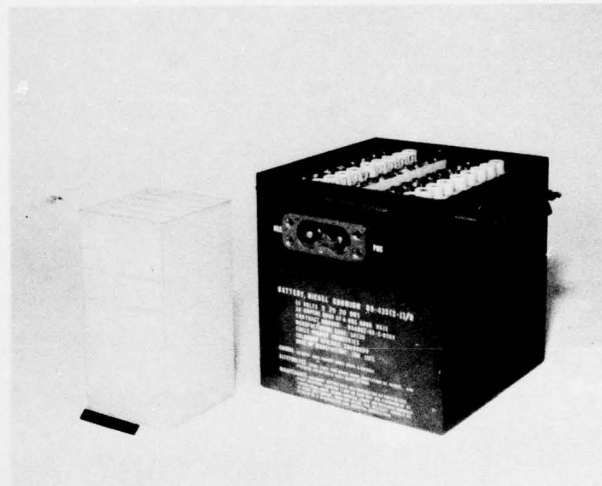


Figure 1. Monoblock Design of Battery BB-433/A.

b. *Battery Container*—Molded fiberglass containers were investigated during the early design phase of this investigation. It was found that the dimensional integrity of the fiberglass material was inferior to metal material; the fiberglass material was also a poor heat conductor. Therefore, the final case design of the monoblock batteries was made of 0.062" Type 304 stainless steel, with an epoxy finish.

#### Monoblock Battery Designs

Four types of monoblock batteries were manufactured and subjected to test. Two types contained 19 cells with .030" and .021" electrodes to provide a direct comparison of the performance of these batteries with the standard 19 cell Battery BB-433/A. The other two types contained 20 cells with .030" and .021" electrodes. A complete battery as manufactured by Eagle-Picher industries, Inc. is shown in Figure 1. The weight of the 19-cell monoblock battery is 83 pounds, the 20-cell battery 87 pounds, and the Standard BB-433/A approximately 75 pounds.

#### Results

Results of tests on the various monoblock batteries follow:

a. *1C rate (30 A) at 80°F*. Figure 2 shows the difference in discharge time and operating battery voltage between Battery BB-433/A and the monoblock batteries at the 1C (30 A) rate at 80°F. In all cases the performance of the monoblock batteries exceeded that of Battery BB-433/A by approximately 15%.

b. *Temperature Rise and Float*—Figure 3 gives the results



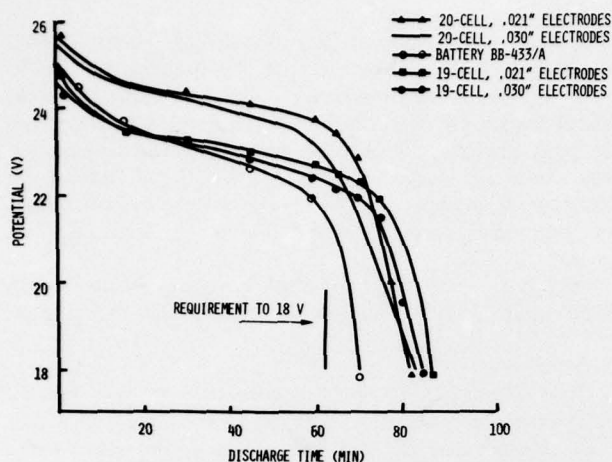


Figure 2. Discharge Time vs Voltage for Battery BB-433/A and Monoblock Batteries.

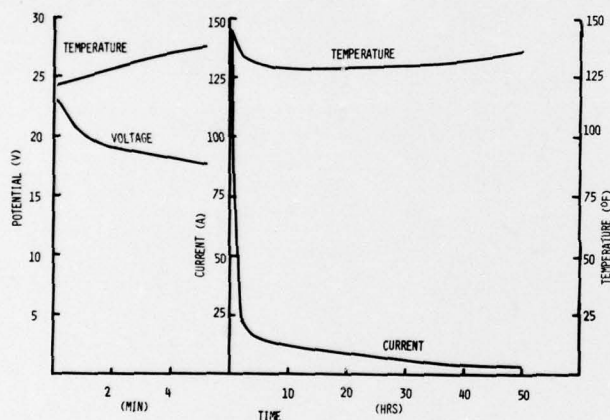


Figure 3. Temperature Rise and Float Data for Monoblock Battery.

of the temperature rise and float test where a fully charged battery is placed in a chamber at 120°F until its electrolyte temperature reaches 120°F, is discharged at the 9C (270 A) rate for 5 minutes, and then immediately placed on a constant potential charge at 28 volts for a specified number of hours. The float requirement for Battery BB-433/A is 24 hours; for the monoblock battery this requirement was extended to 50 hours. After the charge is completed the battery is discharged at the 1C (30 A) rate. On discharge the monoblock battery delivered 65.5 minutes of performance, 9% above the requirement of 60 minutes. Also, the center cell link temperature stayed below the required 160°F maximum temperature during float.

c. *Low Temperature*—Figure 4 shows that the monoblock battery, when discharged at a 9C rate (270 A) at -40°F, delivered 5 minutes of service. Battery BB-433/A has a requirement of 3 minutes at an 8C rate (240 A) at -22°F, and under production testing delivers about 4.5 minutes of service. The monoblock battery delivered better service at a higher rate at approximately 20°F lower ambient temperature.

d. *High Temperature Retention of Charge*—Figure 5 shows results of a discharge and temperature rise of the mono-

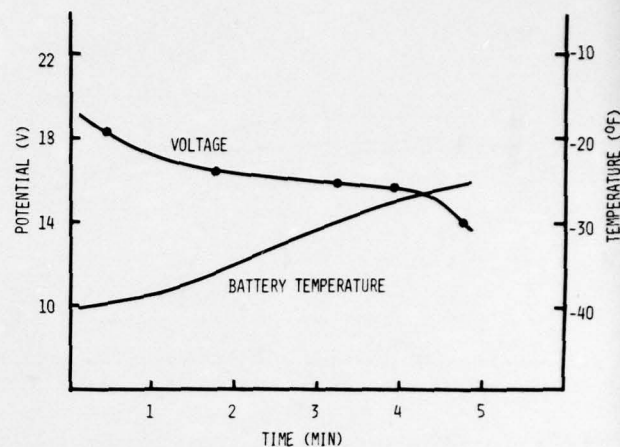


Figure 4. Low Temperature Discharge Data for Monoblock Battery.

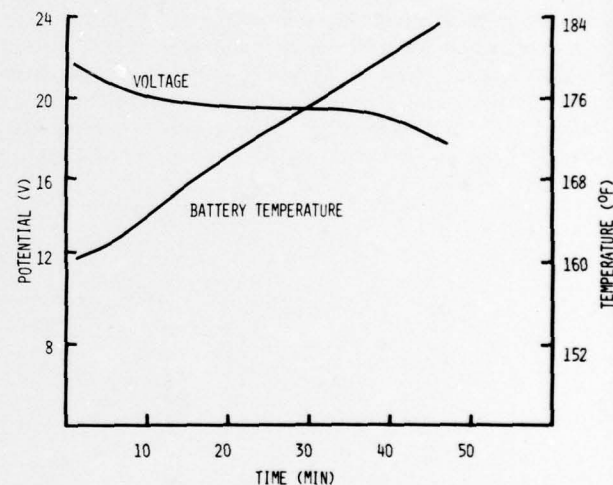


Figure 5. High Temperature Retention of Charge for Monoblock Battery.

block battery at the 1C (30 A) rate at 160°F after a 4 day stand at 160°F. The battery exceeded the normal vented battery requirement of 40% of the rated capacity of the battery by almost a factor of 2.

e. *Duty Cycling*—The duty cycling regime<sup>3</sup> included the following:

Aircraft Start: Two 20 second discharges through a .0166 ohm resistor (approximately 750 A) in a 5 minute period

Aircraft Operation: Charge from a 28 V constant potential source (300 A input) for one hour, 55 minutes.

Rest at Airport: Two hour OCV rest.

Battery BB-433/A and the monoblock batteries. The requirement for Battery BB-433/A is 28 cycles, and for the monoblock batteries it was established at 100 cycles. However, cycling was extended to 250 cycles or to the point of failure for the monoblock batteries. The 19 cell, .030" electrode designed monoblock battery failed at cycle 183. A post mortem examination revealed that the weld at the tabs had separated

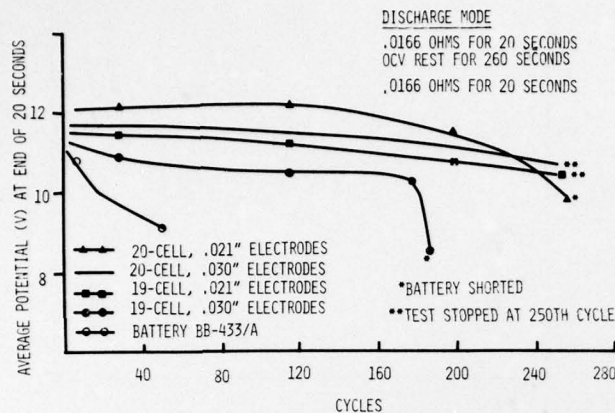


Figure 6. Duty Cycling of Battery BB-433/A vs Various Designs of Monoblock Battery.

and that edge shorts on the side of the cell had developed. Edge shorts also were the cause of failure at the 248th cycle of the 20-cell, .021" electrode design. Improvement in tab welding procedures, such as projection welding, and reduction of the width of the electrodes by about .2 inch to prevent possible buckling of electrodes during assembly, should correct

these deficiencies. Although the 19-cell, .021" electrode and the 20-cell, .030" electrode monoblock batteries lasted 250 cycles without failure, the battery with the thinner electrode, 20-cell design delivered the highest plateau potentials during the pulse discharges. It is to be noted that constant potential charging at a 28 volt level was found to be inadequate for charging the batteries and, therefore, periodic manual cycling was performed every 25 cycles to restore the batteries' capacities.

f. *Other Tests*—The monoblock batteries met the MIL-E-5422 requirements for humidity, shock, vibration, and altitude.

#### Conclusions

The monoblock designed battery met all the specified requirements for electrical, physical, and environmental tests even though some of these requirements were more severe than those specified for the standard battery, BB-433/A.

#### REFERENCES

1. S. A. Duze, "Redesign of Battery BB-433/A," Proc. of Twenty-Third Annual Power Sources Conference, May 1969.
2. J. M. Hill and W. K. McCarter, "Battery BB-433 (X-1)/A," Final Report, Contract DAAB07-69-C-0269 (ECOM), Eagle-Picher Ind. Inc., December 1973.
3. S. A. Duze, "Engineering Evaluation of Aircraft Batteries," R & D Technical Report ECOM-3456, July 1971.